

**THE TRANSLOCATION OF GOLDEN PERCH,
MURRAY COD AND AUSTRALIAN BASS, INTO AND
WITHIN WESTERN AUSTRALIA, FOR THE PURPOSES OF
RECREATIONAL STOCKING, DOMESTIC STOCKING
AND COMMERCIAL AND NON-COMMERCIAL
AQUACULTURE**

A DISCUSSION PAPER

FISHERIES MANAGEMENT PAPER NO. 174

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OPPORTUNITY FOR PUBLIC COMMENT

This discussion paper has been prepared to provide information to assist in assessment of the possible impact of the translocation of golden perch (*Macquaria ambigua*), Murray cod (*Maccullochella peelii peelii*) and Australian bass (*Macquaria novemaculeata*) into and within Western Australia, for the purposes of recreational stocking, domestic stocking, commercial and non-commercial aquaculture.

In assessing the translocation of any aquatic species, economic and social benefits must be balanced with biological and environmental risks.

Comments on this discussion paper are sought from all stakeholders, including industry members, existing and potential aquaculture farmers, recreational fishers, relevant community interest groups, government agencies and interested members of the public.

To ensure your submission is as effective as possible, please:

- Make it clear and concise;
- List your points according to the topic sections and page numbers in this paper;
- Describe briefly each topic or issue you wish to discuss;
- Say whether you agree or disagree with any, or all, of the information within each topic or just those of specific interest to you. Clearly state your reasons, particularly if you disagree, and give supporting sources of information, where possible.
- Suggest alternative solutions, where possible, to address any issues that you disagree with.

A list of suggested topics and issues that may be considered for comment is provided in Appendix 1.

Following the publication of this discussion paper and the public comments received, a draft policy will be developed. This policy will propose areas within Western Australia where stocking may or may not be permitted, along with any constraints on importing these three species into and within Western Australia.

The information provided in this paper should not be considered as conclusive and stakeholders are encouraged to consider additional information from other sources in providing the basis for comment.

Your comments would be appreciated by 5 March 2004 and should be marked to the attention of the Translocation Officer, Fish and Fish Habitat Protection Program, and addressed to:

Executive Director
Department of Fisheries,
Locked Bag 39
Cloisters Square Post Office,
PERTH WA 6850

Even if you do not wish to comment on this discussion paper, you may still register your interest in receiving a copy of the draft policy paper on the matter by providing written notification marked to the attention of the Translocation Officer and addressed as above.

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SECTION 1 INTRODUCTION

1.1 Background and objectives

For a number of years, interest in enhancing recreational fishing opportunities and developing aquaculture industries has stimulated debate on the translocation of non-endemic species for these purposes.

Three species of Australian fish that are endemic to the eastern states, but non-endemic to Western Australia, have been suggested for potential recreational stocking and aquaculture opportunities. The species suggested for translocation are:

- Golden perch (*Macquaria ambigua*);
- Murray cod (*Maccullochella peelii peelii*); and
- Australian bass (*Macquaria novemaculeata*).

These fish species, collectively referred to in this paper as the ‘Murray-Darling species’, all belong to the *Percichthyidae* family, which is restricted to the temperate regions of eastern Australia and South America.

The number of fish species available for aquaculture and recreational stocking purposes are limited, and dependent upon available aquaculture technologies, species-specific aquaculture requirements, recreational fishing qualities, species characteristics and behaviour. Should the translocation of any species be undertaken for either of these purpose, prior consideration must be given to the potential for each species to:

- Impact on the genetic diversity of Western Australian species;
- Impact on the natural environment and biodiversity of West Australian species; and
- Introduce disease.

This discussion paper aims to identify the issues associated with the translocation of golden perch, Murray cod and Australian bass for recreational stocking, domestic stocking, commercial and non-commercial aquaculture, and provide information on these issues.

Through this process, further consideration may be given towards the development of a policy and associated management framework for the stocking and the aquaculture of these species. To achieve this, the Department of Fisheries and the Fish Research Group at Murdoch University has provided some initial information on the biology, ecology, diseases, hatchery techniques and aquaculture potential of these three species.

This discussion paper and the comments subsequently received from the general public and stakeholders will form the basis of a draft policy to establish whether, and under what circumstances, these species could be introduced into and stocked within Western Australia.

Following the receipt of comments on the draft policy, the Department of Fisheries will prepare and distribute a final policy to all interested stakeholders.

The final Murray-Darling species translocation policy will ultimately provide for the sustainable development of both recreational stocking activities and aquaculture in Western Australia, detailing:

- Conditions under which the translocation of golden perch, Murray cod and Australian bass may be undertaken into and within Western Australia.
- Conditions under which the stocking of golden perch, Murray cod and Australian bass may, or may not, be permitted for the purpose of recreational stocking, domestic stocking, commercial and non-commercial aquaculture within Western Australia.

1.2 The translocation of non-endemic species

Translocation of non-endemic species is the movement of organisms beyond their natural range and/or to areas within their natural range that have genetic stocks and/or populations distinct from those in the source area (Ministerial Council on Forestry, Fisheries and Aquaculture, 1999). This infers that the translocation of non-endemic species may include species imported into a State, Territory or Country, and those moved within a State, Territory or Country to regions in which they did not previously exist.

Several of the freshwater species currently found in Western Australia have been introduced from other states or countries. These include the yabby (*Cherax albidus* [Australian range extended]), redfin perch (*Perca fluviatilis* [introduced]), marron (*Cherax tenuimanus* [Western Australian range extended]), trout (*Oncorhynchus mykiss* and *Salmo trutta* [introduced]) and silver perch (*Bidyanus bidyanus* [Australian range extended]).

It should be noted that this list is ‘indicative’, rather than being a comprehensive list of the introduced species in Western Australia.

In 1996, the Standing Committee on Fisheries and Aquaculture acknowledged the need for a common approach to the translocation of aquatic organisms. As a result, the Environment and Health Committee prepared a national policy on the matter. In 1999, the Ministerial Council on Forestry, Fisheries and Aquaculture released the *National Policy for the Translocation of Live Aquatic Organisms*.

The translocation of non-endemic species into or within Western Australia requires the prior written approval or written authority of the Executive Director of the Department of Fisheries, in accordance with Regulation 176 of the *Fish Resources Management Regulations 1995*.

The procedure used to assess applications for the translocation of non-endemic species for aquaculture, recreational stocking and enhancement purposes has been developed through a Memorandum of Understanding (MoU) between the Department of Fisheries and the Environmental Protection Authority. Through this MoU, both parties have established procedures for the efficient implementation of their duties, facilitating the administration of their responsibilities under the *Environmental Protection Act 1986* and the *Fish Resources Management Act 1994*.

The MoU also provides for the use of species-specific translocation protocols. Applications to translocate non-endemic species for other purposes are considered on a case-by-case basis by the Department of Fisheries.

Issued pursuant to Section 246 of the *Fish Resources Management Act 1994*, the Ministerial Policy Guideline No. 5, entitled *The Aquaculture and Recreational Fishing Stock Enhancement of Non-Endemic Species in Western Australia*, was developed to assist in the consideration of applications for the translocation of non-endemic species into and within Western Australia for aquaculture and stock enhancement purposes. The five main policy guidelines associated with this latter document may be summarised as follows:

- i. Authorisation of the translocation of non-endemic species will be subject to a risk management assessment being carried out.
- ii. The assessment will be undertaken by the Department of Fisheries, within the context of an application and translocation synopsis provided by a proponent. Authorisation of the translocation would be conditional upon the assessment showing that the translocation would present a low risk to the environment.
- iii. The risk assessment must be based on the best scientific data available for the species and the environment into which it is to be introduced.
- iv. The translocation application will be referred to relevant industry groups for consultation and public comment sought before any decisions are made.
- v. The translocation decision should balance the potential economic and social benefits against any potential biological and environmental risks.

Following the above principles, translocation policies have been developed in Western Australia for redclaw crayfish (*Cherax quadricarinatus*), silver perch (*Bidyanus bidyanus*), silver-lip pearl oyster (*Pinctada maxima*) and barramundi (*Lates calcarifer*). A policy on the translocation of brown and rainbow trout is currently being developed.

SECTION 2 RISK ASSESSMENT AND ECOLOGICALLY SUSTAINABLE DEVELOPMENT

2.1 Risk assessment

As detailed in Section 1.2, any decision made in relation to the translocation of non-endemic species must consider the potential social and economic benefits in light of any potential biological or environmental risks. It is acknowledged that translocations undertaken for both recreational stocking and aquaculture purposes may have considerable potential social and economic benefits associated with these activities.

However, there is also a potential risk that any fish species that is translocated from one area to another may possibly lead to disease introduction and/or the establishment of feral populations. In turn, this may cause local species extinctions, population fragmentations and disruptions to food chains and webs.

Only a few of the species introduced into Western Australia so far are generally accepted as having been beneficial. For example, species introduced in the past range from an uncontrollable feral pest such as the mosquito fish (*Gambusia* species), to a valued commercial and social commodity such as brown and rainbow trout.

Western Australia's recreational trout fishery demonstrates that there are potential social and economic benefits to be gained from freshwater fisheries. Therefore, it may be suggested that there is potential for achieving similar benefits from the establishment of Murray-Darling species in the overall Western Australian freshwater recreational fishery. However, it should be noted that such introductions may also put existing recreational fisheries, as well as other West Australian aquatic species, at risk.

In addition, there are a number of aquaculture facilities dependent on the aquaculture of a range of non-endemic species, which may have the potential to provide economic benefits to the State. These may be further developed through the adoption of Murray-Darling species for aquaculture purposes.

However, as per the Ministerial Policy Guideline No.5, the translocation of non-endemic species for aquaculture and recreational fishing purposes into and within Western Australia must not be authorised until a risk management assessment has been undertaken prior to translocation. As outlined in the Ministerial Policy Guideline No.5, any assessment undertaken should consider the potential of the introduced species to:

- Impact on genetic diversity;
- Impact on the natural environment and the biodiversity of native species; and
- Introduce disease.

2.2 Ecologically Sustainable Development

Prior to undertaking any risk analysis, it is important to note the core objectives and guiding principles of Ecological Sustainable Development (ESD) (Fisheries Management Paper No. 157) as adopted from the National Strategy.

2.2.1 *Core objectives*

- To enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare for future generations.
- To provide for equity within and between generations.
- To protect biological diversity and maintain essential ecological processes and life support systems.

2.2.2 *Guiding principles*

- Decision making processes should effectively integrate both long and short term economic, environmental, social and equity considerations.
- Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
- The global dimension of environmental impacts of actions and policies should be recognised and considered.
- The need to develop a strong, growing and diversified economy, which can enhance the capacity for environmental protection, should be encouraged.
- The need to maintain and enhance international competitiveness in an environmentally sound manner should be recognised.
- Cost effective and flexible policy instruments should be adopted, such as improved valuation, pricing and incentive mechanisms.
- Decisions and actions should provide for broad community involvement on issues which affect them.

Issues and information identified through the development of this discussion paper, and through comments received in response to stakeholder consultation, will be considered in line with the above risk assessment and ecologically sustainable development objectives and guidelines.

This process provides for the establishment and implementation of a management policy and framework, to ensure any future translocations are conducted in an ecologically sustainable manner, and for the sustainable development of both the recreational and commercial sectors.

SECTION 3 ENVIRONMENTAL FEATURES AND INLAND FISH RESOURCES IN WESTERN AUSTRALIA

3.1 Western Australia's freshwater fish fauna

Western Australia has approximately 70 native freshwater fish species, and of these eight could be considered recreational angling species. In addition, there are a number of estuarine fish species that are heavily targeted by anglers, with some species penetrating large distances upstream (e.g. black bream, yellow-tail trumpeters). Also popular with recreational fishers are a number of species of crustaceans found in the south-west (e.g. marron, gilgies and koonacs).

To date, there are a number of non-endemic fish species that have been introduced or escaped into the waters of inland Western Australia. These include brown and rainbow trout, redfin perch, two species of decapod crustacean (yabbies and redclaw), and a number of introduced aquaria/ornamental species, including mosquito fish (*Gambusia* species), swordtails, guppies, one-spot livebearers, goldfish, carp and tilapia.

When considering the translocation of any freshwater species into or within Western Australia, the State is generally divided into geographic areas defined by natural drainage basins.

While the information below provides information on all drainage divisions within Western Australia, it is likely that any potential translocation of the three Murray-Darling species will, for both recreational stocking and aquaculture purposes, be considered mainly for the mid-west and southern areas within the State. This is due to the environmental tolerances of the species proposed and water resource limitations experienced in other areas of the State.

3.2 South-western drainage division

(See Figure 1)

Many of the rivers of the 'south-west' (i.e. from Geraldton to Esperance) are subject to summer droughts and are frequently saline. Pools in these rivers act as refuges for both fish and crustaceans.

Freshwater lakes are most common to the Swan Coastal Plain and are generally shallow, with many becoming dry during the summer months (Allen 1989). Many of these lakes have become somewhat degraded by eutrophication.

There are a large number of salt lakes, and salt-affected water bodies, within this division, including a large number of farm dams throughout the Western Australian wheatbelt. These dams are generally small (less than 1 hectare) and often filled with saline groundwater.

Many of the private farms in the region grow yabbies or marron, while aquaculture trials in the salt-affected regions include black bream (*Acanthopagrus butcheri*), rainbow trout (*Oncorhynchus mykiss*) (Maguire & Sarre, 1999) snapper (*Pagrus auratus*) and barramundi

(*Lates Calcarifer*). There are also a number of people farming small endemic fishes, such as western pygmy perch (*Edelia vittata*) and western minnows (*Galaxias occidentalis*), as ornamentals and for midge/mosquito control. It should be noted that non-endemic silver perch (*Bidyanus bidyanus*) has recently been found in the Swan coastal plain (Molony, pers. com.).

The freshwater fish fauna of this region comprises 14 species (including eight endemic ones), with several of these being primarily estuarine. Inland recreational fishing opportunities include introduced trout (*Oncorhynchus mykiss* and *Salmo trutta*) and redfin perch (*Perca fluviatilis*), which are widespread over the south-western corner of this division. Endemic marron (*Cherax tenuimanus*), which support an important licensed inland recreational freshwater fishery, are found in most impoundments and river systems.

Both juvenile and adult marron (and other decapods) are heavily preyed on by redfin perch in the rivers and dams of this region (Pen & Potter, 1992; Morgan & Gill, 1996; Beatty, 2000). Beatty (2000), together with Bergman (1988) and Diehl (1988), found that redfin perch change their foraging behaviour at night, feeding more heavily on slower-moving prey such as marron and gilgies.

Endemic freshwater cobbler (*Tandanus bostocki*) also prey heavily on marron (Hewitt, 1992). The former occur in most of the larger rivers of this division, but are not heavily targeted by recreational fishers.

Within the estuarine regions of south-west rivers, black bream (*Acanthopagrus butcheri*) is the most important recreational fishing species, while blue swimmer crabs (*Portunus pelagicus*) and western school and king prawns (*Metapenaeus dalli* and *Penaeus latissulcatus*) are the most important crustaceans.

While Murray cod are believed to have disappeared from the Swan River and Lake Grassmere (Lake Powell), Murray cod and golden perch have previously been stocked into the Swan-Avon River (near York and Beverley) and Lake Grassmere (Lake Powell - near Albany) in the late 1800s (Coy, 1979).

3.3 Pilbara drainage division

(See Figure 1)

The Pilbara drainage division extends from Geraldton in the south to Port Hedland in the north, encompassing some large river systems, including the Murchison, Gascoyne, Fortescue, Ashburton and De Grey. Rainfall over this division is generally sparse. As a consequence, rivers can be mainly dry for several years in succession, with many of the division's fishes relying on permanent pools for survival during droughts.

The division is subjected to very hot summers, with occasional cyclones causing torrential downpours and flash-flooding. The rivers within it are generally slow-flowing, ranging from clear-watered in inland areas to highly turbid nearer the coast. The vast majority of existing supplies come from ground water, with the bore fields of the Yule and De Grey Rivers and the Millstream aquifer supplying the West Pilbara Scheme.

The harsh climatic conditions are reflected in the low number of fish species in the Pilbara drainage division. The 14 species that are regular inhabitants of its freshwater are dominated by three species of grunter (one endemic), three of gudgeon (two endemic), two of gobies, one species each of the fork and eel-tailed catfish (cobbler), one herring species, one endemic hardyhead species, barramundi (*Lates calcarifer*), one species of rainbowfish, an endemic species of eel and a garfish species.

Recreational fishing opportunities include the highly-prized barramundi, grunters (spangled perch, yellowtail), black bream, mangrove jack and cobbler.

3.4 Kimberley drainage division

(See Figure 1)

The Kimberley drainage division covers the relatively hilly terrain of the far north of Western Australia (north and east from Broome) and the adjacent portion of the Northern Territory. The principal river systems of the Kimberley include the Ord, Pentecost, Drysdale, King Edward, Mitchell, Prince Regent, Isdell, Meda and the Fitzroy. These systems are seasonal, and all rivers except the Ord are dry by the end of May.

The tropical climate of the division is characterised by heavy monsoonal rains and extensive flooding during summer and early autumn (November to April). The dry season (May to October) provides sunny days and cooler nights as the trade winds flow from central Australia, with very little rainfall from late winter to spring.

Despite the two dominant wet and dry seasons, this is one of the wettest areas of Australia, and the abundant rainfall, tropical climate, and well-dissected landscape have fostered a diverse fish fauna, by Australian standards. There are around 70 species, dominated by grunters (14 species) and gudgeons (10 species). Almost one-third of the species are endemic to the division, with many endemic to individual rivers.

An increasingly important recreational fishery centres on barramundi, while inland aquaculture ventures have been established using barramundi and crocodiles. There is a commercial fishery for wild-caught barramundi and catfish (silver cobbler).

3.5 Zone of uncoordinated drainage

(See Figure 1)

This drainage division is comprised of ephemeral water bodies, while its fish fauna comprises those species that re-invade the water bodies of the lower southern region of the State from neighbouring divisions during floods. The introduced goldfish (*Carassius auratus*), mosquitofish (*Gambusia holbrooki*) and yabbies have been recorded in the region (Morgan, unpublished data), as well as the endemic spangled perch (*Leiopotherapon unicolor*) (WA Museum Records).

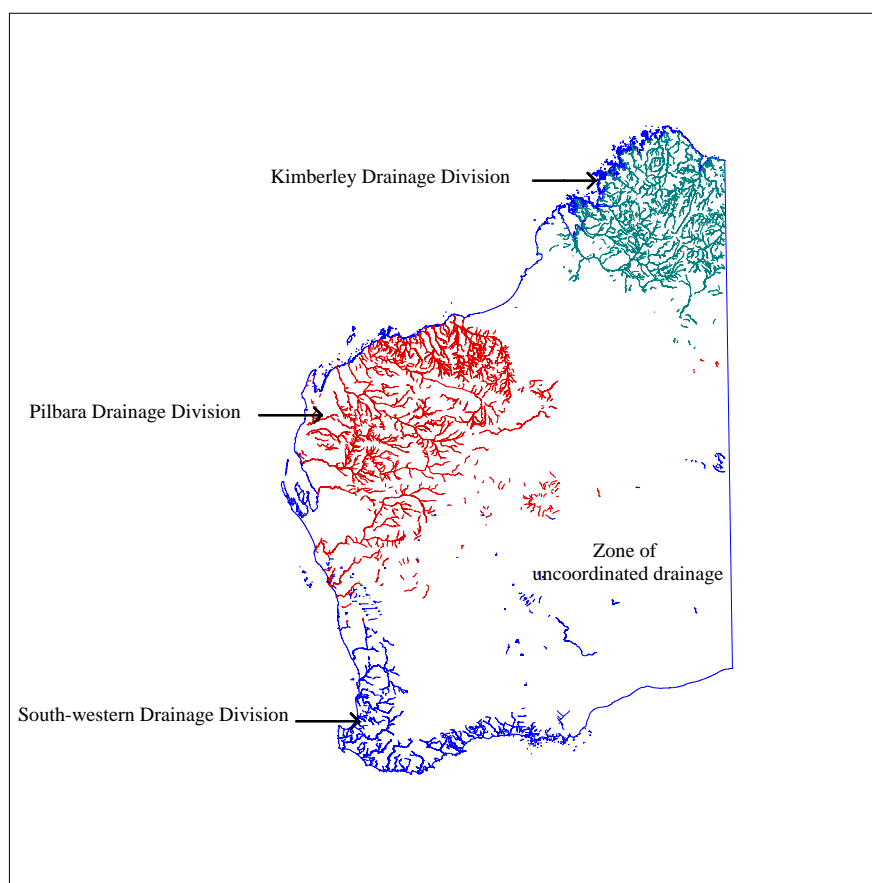


Figure 1 West Australian Drainage Divisions

SECTION 4 THE BIOLOGY AND ECOLOGY OF GOLDEN PERCH

4.1 Natural history, native range and habitat of golden perch

The golden perch (*Macquaria ambigua*) is endemic to the Murray-Darling River system in south-eastern Australia, with several genetically and morphometrically distinct populations identified from the Lake Eyre and Bulloo internal drainage systems of Queensland, New South Wales, South Australia and the Dawson-Fitzroy River system of Queensland (MacDonald, 1976; Brumley, 1987; Musyl & Keenan, 1992). This species is now rare in Victoria and has disappeared from large areas of its native range, due primarily to habitat degradation through the construction of dams and weirs that obstruct its upstream migration (Brumley, 1987).

In contrast, golden perch are relatively common in much of the Murray-Darling system, and are by far the most abundant of the popular angling species in the system. Its distribution in the system has increased over the last 20 years, due to the stocking of hatchery-reared fingerlings (Rowland pers.com.). There is no sexual dimorphism.

While they complete their lifecycle in freshwater, golden perch are also caught in estuaries (Langdon, 1987; Bell, pers. com.). Thus, this species is able to exist in a wide range of habitats and can tolerate a very wide range in salinity (i.e. 0 to 33 ppt) and temperature (4 to 37°C) (Langdon, 1987). Langdon (1987) demonstrated that both juveniles and sub-adults could survive in seawater.

Golden perch were stocked into the Swan-Avon River in the late 1800s (Coy, 1979), with a number having recently been captured in the Swan River (Lawrence, 1993; Sarre, pers. com.).

4.2 Age, growth and reproduction of golden perch

Previous authors believed that golden perch spawning occurred only in spring or summer, when water temperatures exceed 23°C, and followed a flood (Lake, 1967a; MacKay, 1973; Gehrke, 1990). However, a recent study of larval recruitment, conducted bi-monthly over three years in a tributary of the Murray River, found that the only recruitment of larvae coincided with a year of “extremely poor winter rains before the breeding season and low daily discharge throughout summer” (Humphries and Lake, 2000).

Furthermore, in the preceding years when discharge was considerably higher and temperature similar, spawning did not occur (Humphries and Lake, 2000).

This species has also bred in farm dams (Merrick & Schmida, 1984) and water supply impoundments (Rowland, 1983a), although this seems to be a rare occurrence usually limited to impounded waters that experience rises in water levels during spring and summer, such as Keepit Dam NSW (Rowland pers. com.). While some individuals have been shown to undergo long migrations prior to spawning, many adults do not migrate prior to spawning (Crook, unpublished data).

In a study by Lake (1967a), fecundity of three fish (2.2 to 2.4 kg in weight) was approximately 500,000 eggs per fish. Mature ova from running ripe golden perch are amber in colour and have a mean diameter of 1.1 mm (Lake, 1967b). Eggs, approximately 3.3 to 4.2 mm in diameter, are colourless, pelagic, non-adhesive and semi-buoyant (Lake, 1967b). Larvae, which hatch after 24 to 33 hours at 2.5 to 3.0 mm, are poorly developed, lightly pigmented, have a large yolk sac and are pelagic (Lake, 1967b; Brown & Neira, 1998).

By contrast, reared larvae are more pigmented than wild-caught larvae (Brown & Neira, 1998). Larvae begin feeding five to six days after hatching (Lake, 1967b; Arumugan & Geddes, 1987; Gehrke, 1990; Rowland, 1996) and development is complete within approximately 18 to 20 days after hatching, when they reach 9.5 to 11.5 mm long (Lake, 1967b).

Growth studies on two populations of golden perch in the Murray-Darling system concluded that this species attains approximately 150 to 250 mm total length (TL) after their first year of life, and 225 to 300, 325 to 425 and 425 to 500 mm total length after their second, third and fourth years, respectively (Figure 2) (Anderson *et al.*, 1992a). The oldest validated age for golden perch has been established in work carried out by Anderson *et al.* (1992a). He found three fish of 16 years that weighed between 2.5 and 4.0 kg and measured approximately 600 mm in total length.

Growth is highly variable among and between different populations (Anderson, *et al.*, 1992a). For example, the heaviest fish recorded by Anderson *et al.* (1992a) was six-years old, approximately 4.9 kg, and measured 600 mm total length, i.e. the same length as the 16-year olds. Fish of up to 760 mm and 23 kg have been reported (Harris & Rowland, 1996) but are rare. Males and females reach maturity at approximately three to four and six-years old, respectively (Gooley *et al.*, 1995).

4.3 Diet of golden perch

Very few studies have examined the diets of wild populations of golden perch. However, those that did found that adults prey heavily on freshwater crayfish - in particular, the world's second largest freshwater crayfish species - the Murray River crayfish *Euastacus armatus* - and fish (Humphries, unpublished data; Merrick & Schmida, 1984; Allen, 1989).

Golden perch feed both during the day and night, either ambush feeding or actively pursuing prey (see references in Merrick and Schmida, 1984). This species therefore has the ability to prey heavily on marron and other West Australian fish species that have essentially evolved in the absence of large piscine predators.

In farm dams, golden perch larvae feed mainly on crustacean zooplankton (copepods and cladocerans less than 350µm) from five-days old (Gehrke, 1990; Rowland, 1996). At 35 days after hatching, the juveniles include chironomid larvae and aquatic insects in their diet (Rowland, 1996). Large fish held in captivity are often fed on fish and crustacea (i.e. yabbies) (Thurstan, pers. com.).

4.4 Behaviour of golden perch

Some mature golden perch have been shown to undergo long spawning migrations, believed to offset the downward flow of eggs and larvae (Reynolds, 1983). While fish were also found to move downstream, the largest upstream migration recorded was 2,300 km, with movements up to 1,000 km not uncommon.

SECTION 5 THE BIOLOGY AND ECOLOGY OF MURRAY COD

5.1 Natural history, native range and habitat of Murray cod

Historically, the Murray cod (*Maccullochella peelii peelii*) has ranged throughout most of the Murray-Darling River system, but been stocked into many public and private waters outside its natural range in south-eastern Australia, and into a number of localities in south-western Australia, e.g. the Swan-Avon River and Lake Grassmere in the late 1800s (Morrissy, 1970; Coy, 1979; Rowland, 1989). Murray cod are believed to have disappeared from both the Swan-Avon River, Lake Grassmere and connecting water bodies.

The Murray cod is now uncommon in most areas and is rare in most Victorian tributaries of the Murray River, due to a host of mostly human impacts. These include over-fishing, de-snagging, altered flow-rates and temperature regimes (through the construction of dams, weirs and levee banks) and competition with introduced species such as redfin perch (Rowland, 1989).

The Murray cod completes its lifecycle wholly in freshwater (Rowland, 1989) and is often found associated with complex habitats, such as logs, holes or other cover (see references in Koehn & O'Connor, 1990).

5.2 Age, growth and reproduction of Murray cod

The Murray cod is one of the world's largest freshwater fish species and has been recorded up to 1,800 mm in length and 113.5 kg in weight (Rowland, 1989). The oldest validated age for this species is 48 years for a 1,200 mm (total length) fish (Anderson, *et al.*, 1992b).

Growth has been shown to be highly variable among and between populations (Figure 2) (Anderson *et al.*, 1992b; Gooley, 1992; Rowland, 1998a). For example, while Rowland (1998a) and Gooley (1992) found no significant difference in growth between males and females, they did find differences in growth between a river and a lake population of Murray cod. In the river population, on average Murray cod attained 119, 192, 261 and 325 mm total length after one, two, three and four years of growth, respectively - compared to 122, 242, 336 and 411 mm total length at the corresponding ages for a lake population.

Known fecundities for Murray cod range from 6,800 eggs for a 480 mm total length fish (weighing 2.1 kg) to 86,600 eggs for a 1,050 mm fish (weighing 22.7 kg), with relative fecundity ranging from 3.2 to 7.6 eggs/gram fish (Rowland, 1998b). Adhesive eggs are three to four mm in diameter and laid on logs, rocks or clay banks (Lake 1967b; Rowland, 1983a; Brown & Neira, 1998).

Spawning occurs annually during spring and early summer (September in most northern populations). The precise time of spawning is apparently dependant on prevailing climatic conditions, and is induced by increasing day-length and water temperatures over 16.5°C. It also coincides with an increase in plankton and aquatic insects (Lake, 1967a; Rowland, 1983b, 1992, 1998b; Cadwallader & Gooley, 1985; Gooley, *et al.*, 1995).

Larvae hatch between six to 11 days at lengths of six to nine mm and have pigmented eyes and a large yolk sac that is reabsorbed by the end of the larval stage (metamorphosis - approximately 10 mm) (Lake, 1967b; Brown & Neira, 1998). The larvae have no pelagic stage and settle directly on the bottom where they usually remain clumped for eight to 10 days, until the yolk sac is absorbed and feeding commences (Brown & Neira, 1998). Males have been observed guarding and possibly fanning the eggs (Rowland, 1983b).

Female Murray cod from the Murray-Darling River system mature in their fourth year (77 per cent of all females) or fifth year (100 per cent) of life, while male Murray cod mature in their third year (15 per cent), fourth year (72 per cent) or fifth year (100 per cent) of life (Rowland, 1998b). Yet age at maturity has been shown to vary, with the youngest mature female in Lake Charlegrark being six years old and males maturing earlier, at three to four years of age (Gooley, *et al.*, 1995). Approximately one per cent of Murray cod in this latter population possessed both female and male gonad tissue and was therefore hermaphroditic (Gooley, *et al.*, 1995).

5.3 Diet of Murray cod

Adult Murray cod are top-order carnivores, and have been reported to consume everything from crustaceans (such as freshwater crayfish), molluscs, frogs, fish, turtles and water birds to terrestrial animals such as possums, mice and snakes (Lake, 1978; McDowall, 1996).

In earthen ponds, Murray cod larvae begin actively feeding on copepods and cladocerans (180-450 µm) at transformation (9 to 11 days after hatching), before including chironomid larvae and other aquatic insects into their diets when 20 to 30 mm long (Rowland, 1992). In such ponds, the availability of zooplankton within two weeks of the completion of yolk-sac absorption is an important factor influencing survival of Murray cod larvae (Rowland, 1992).

For rearing, densities of 250-5,000 zooplanktons/litre should be maintained (Rowland, 1992). Alternatively, larvae can be reared using newly-hatched brine shrimp (*Artemia*) (Cadwallader & Gooley, 1985).

5.4 Behaviour of Murray cod

Radio tracking and tagging has shown that adult Murray cod undertake large pre-spawning migrations (up to 200 km), often returning to the exact snag they left (Reynolds, 1983; Koehn, pers. com.). Murray cod are generally aggressive and territorial, with optimum stocking densities for broodstock being low (Rowland, 1988; Thurstan, pers. com.).

SECTION 6 THE BIOLOGY AND ECOLOGY OF AUSTRALIAN BASS

6.1 Natural history, native range and habitat of Australian bass

The Australian bass (*Macquaria novemaculeata*) is restricted to the coastal rivers and lakes to the east of the Great Dividing Range, from the Mary River in Queensland south to the Gippsland Lakes in Victoria. Its distribution is often confused with that of the very similar estuary perch, *Macquaria colonorum* (Williams, 1970; Harris, 1987; Harris & Rowland, 1996).

There are no records of this species being introduced into the waters of Western Australia.

The natural abundance of Australian bass has declined severely, as much of the species' habitat is now obstructed by dams and weirs which block its migration paths. Flood mitigation practices and acidification of streams also affect spawning cues and juvenile mortality, respectively (Merrick & Schmida, 1984; Harris, 1988; Harris & Rowland, 1996).

Australian bass are found in a wide range of habitats, including headwater and main channel streams, floodplains of wetlands, and estuaries, where they experience (and tolerate) a diversity of conditions and other environmental factors (Harris, 1988). Williams (1970) found that Australian bass enter the sea after floods.

The presence of juvenile Australian bass in ponds and reservoirs has led many authors to believe that spawning takes place in such habitats (see Williams, 1964; and references in Harris, 1986). However, Harris (1986) believes that these fishes have been transported and released into such water bodies by anglers - while Australian bass may be stocked and held successfully in farm dams, they are unlikely to breed. The species' slow growth rate is hampered in such environments by their aggressive behaviour, resulting in stunted fish populations.

6.2 Age, growth and reproduction of Australian bass

While Australian bass have been recorded to about 600 mm in length and 3.8 kg in weight, the lack of discrimination between this species and the similar-looking estuary perch puts doubts on such records (Williams, 1970; Harris, 1987). The Australian bass is a long-lived species, with the oldest validated age being 22 years (Harris, 1985a). Males and females mature at three and five to six years old respectively.

In the wild, spawning occurs between mid-May and December, but varies from the northern part to the southern part of the range of this species. The success of Australian bass in breeding is thought to be reduced during periods of drought (e.g. see Harris, 1986; McCarraher, 1986; Battaglene & Selosse, 1996).

Australian bass are known to migrate to estuarine waters (salinity of approximately one-third seawater) to spawn, and are often confused with estuary perch (Harris, 1986). Harris (1986) found sperm viability of Australian bass to be zero in salinities of less than 6 ppt, with sperm longevity decreasing from 18 minutes at 12 ppt to six minutes at 35 ppt (i.e. seawater). While

the mean fecundity of 35 Australian bass was 441,200, actual fecundities ranged from 49,000 to 1,429,000 oocytes (Harris, 1986).

Female Australian bass grow faster than males and reach a larger asymptotic size (see Figure 2) (Harris, 1987). This marked reverse sexual dimorphism between male and female Australian bass may be an adaptation to:

- The different migration distances and gamete energy requirements of the sexes; and
- Earlier age at maturity of the males, their different habitat and diets (Harris, 1987).

The marked flexibility the Australian bass shows in its diet, reproduction, growth rates and length-at-age, together with its high fecundity and longevity, has enabled it to successfully adapt to an environment that varies widely and unpredictably (Harris, 1985a, b, 1986, 1987, 1988).

Australian bass have a slow growth rate relative to the two other Australian members of the *Percichthyidae* family being discussed, i.e. golden perch and Murray cod (Figure 2) (Harris, 1987). Harris (1987) found that females of this slow-growing, long-lived species required between five to nine years growth to attain the previous 280 mm minimum legal total length in NSW, and that this size limit exceeded the asymptotic length of males in tidal waters (271 mm) (Figure 2) (Harris, 1987).

Harris (1987) found that male Australian bass in tidal waters required, on average, five years to reach a size of 200 mm in length, with males undergoing a further four years of growth and attaining only 230 mm on average. Similarly, the females of this species in tidal waters attained only 220 mm in five years and 220 mm in nine years (Harris, 1987). Females in a lagoon grew marginally faster and attained 290 mm at five years of age, compared to 330 mm after nine years.

These slow growth rates would make Australian bass undesirable as an aquaculture species, and should be considered if the species is proposed for recreational stocking purposes. The propagation of this species in eastern Australia is generally for recreational stock enhancement, due to the depletion of natural populations.

6.3 Diet of Australian bass

The Australian bass is a top predator. An examination of the stomachs of 552 adults and yearlings was found by Harris (1985b) to contain almost every available prey type, including: fish (which were the most important food source recorded in Australian bass); insects (such as coleopterans, dipterans, hemipterans, odonatans and trichopterans); crustaceans (such as crayfish, shrimp, prawns, crabs, copepods and cladocerans); and terrestrial vertebrates (such as skinks, frogs and birds and plant material).

While the diets of Australian bass varied significantly between habitat and season, insects, fish and large crustaceans were the most important prey types (Harris, 1985b).

6.4 Behaviour of Australian bass

Australian bass are catadromous, with females migrating downstream from upland riverine or lagoon habitat into the brackish water of the estuaries to breed with the males, who remain in the estuarine environment (Harris, 1988). In comparison to female Australian bass, males are often found in large schools (van der Wal, 1989).

Although large numbers of Australian bass do not usually enter water of salinity greater than 10ppt, they are able to penetrate higher salinities when breeding in estuaries (i.e. 20ppt) and moving between tributaries of river systems. Furthermore Australian bass have been caught up to 5 km off the coast after heavy floods (Williams, 1970), highlighting their potential to disperse from one estuary/river system to another.

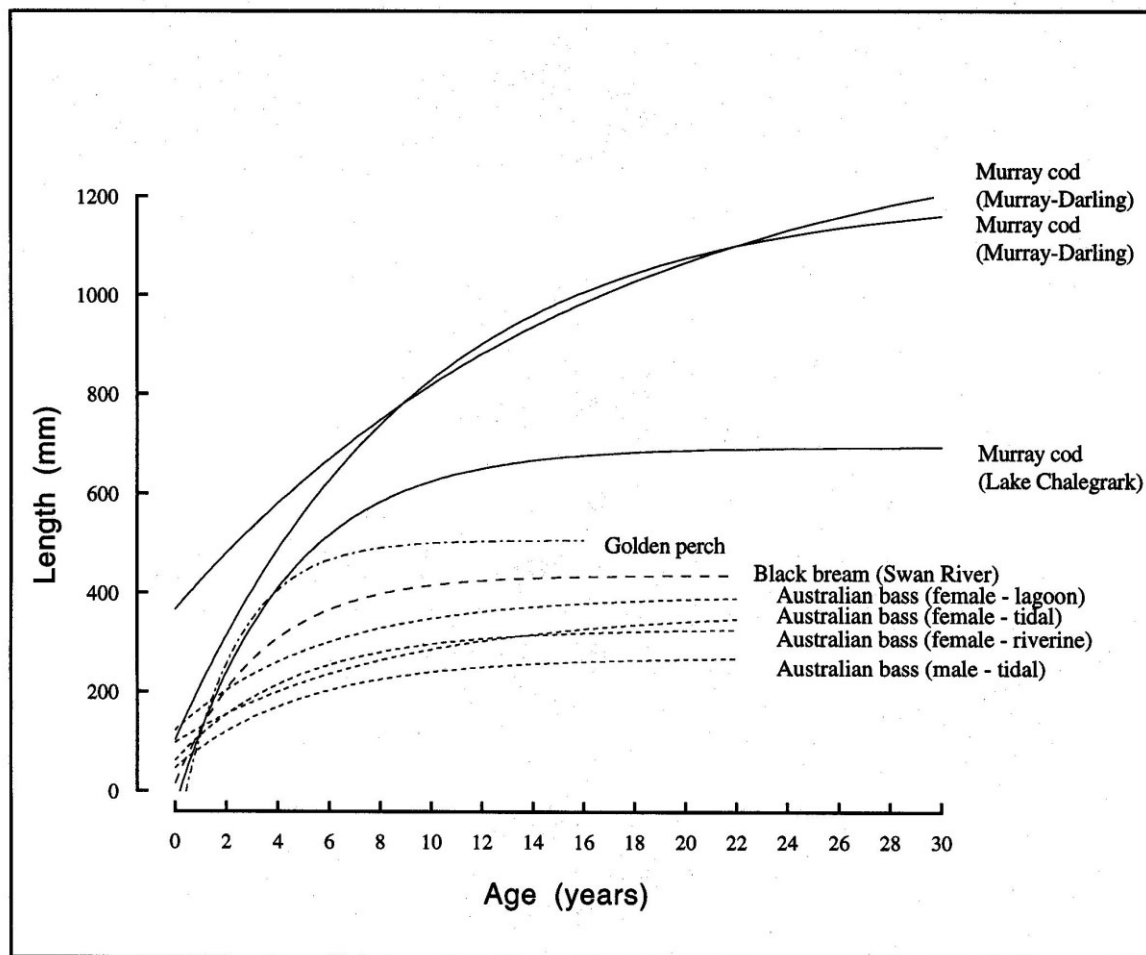


Figure 2 Von Bertalanffy growth curves for Murray cod, golden perch, Australian bass and black bream.

Taken from Harris (1987), Anderson et al. (1992a,b), Gooley (1992), Rowland (1998a) and Sarre and Potter (2000).

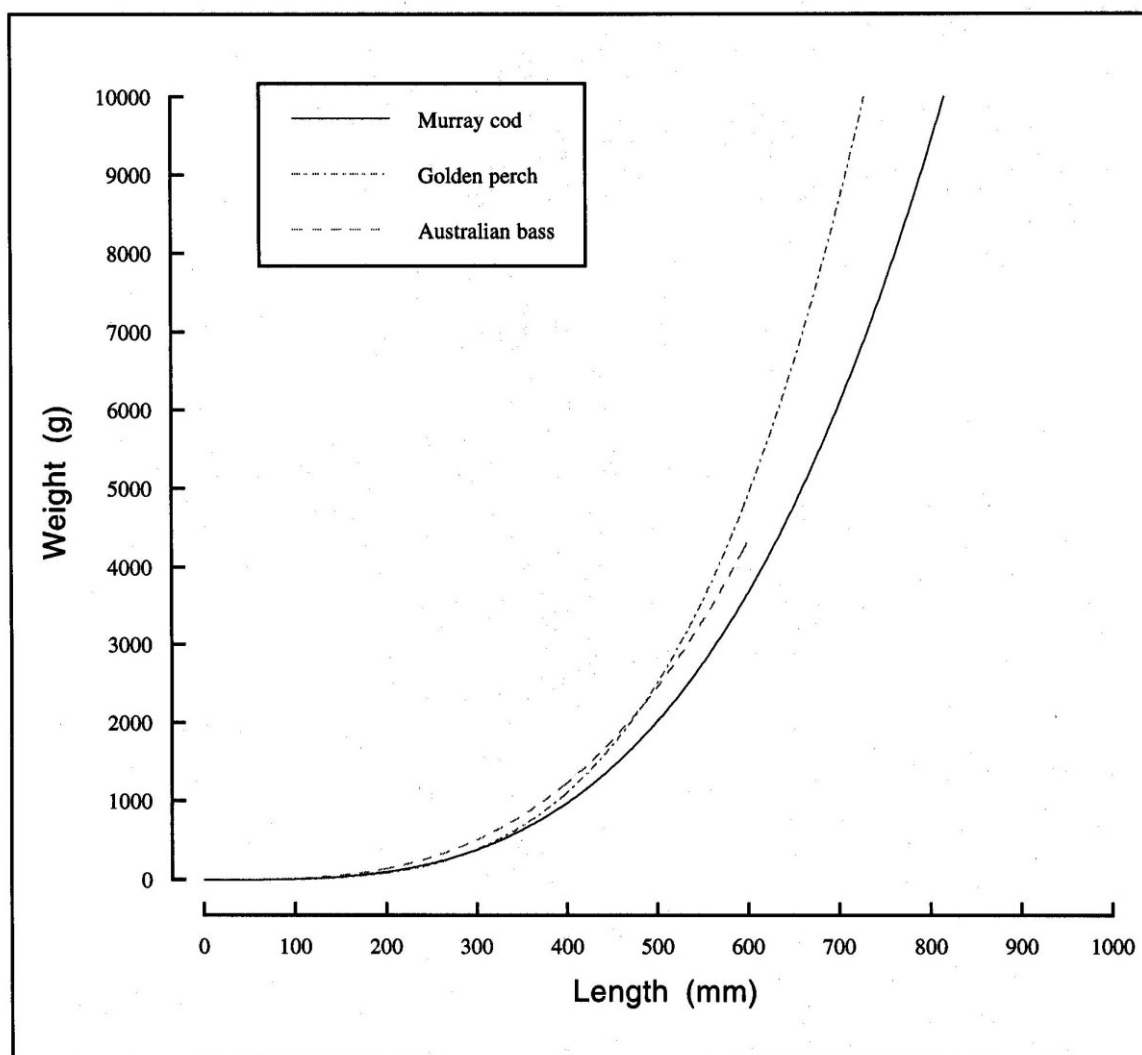


Figure 3 Length-weight relationships for Murray cod, golden perch and Australian bass.

N.B. The lengths of Murray cod and golden perch are in total length, while the lengths for Australian bass are fork length (Harris, 1987; Anderson *et al.* 1992a; Rowland 1998a).

SECTION 7 AQUACULTURE

7.1 Establishment of an ecologically sustainable, commercially viable aquaculture industry

For the past 15 years, the worldwide harvest of food-grade wild fish has remained static at around 120 million tonnes (FAO 2000). With the continued growth of the world's population, the demand for seafood has increased and aquaculture has tried to meet this demand. In this climate of increasing demand for seafood and fully exploited wild-capture fisheries, aquaculture offers an alternative to the latter that also provides associated business opportunities.

The annual world production of aquaculture is currently valued at US\$61 billion, and is growing at 10 per cent each year (FAO 2000). In Australia, aquaculture generates around \$678 million in revenue per year. This constitutes approximately 29 per cent of the total value of Australia's fisheries production, and is forecast to increase to \$2.5 billion by 2010, growing at 13 per cent each year (ABARE 2001). This makes aquaculture Australia's fastest-growing primary industry.

Nationally, over 40 species are currently being farmed commercially (Aquaculture Industry Action Agenda, 2002). However, only five species make up 93 per cent of aquaculture production by value - pearls, edible oysters, tuna, salmon and prawns. The principles that have underpinned the success of these aquaculture sectors have been:

- A market lead;
- A business oriented approach that utilises proven production technology;
- Technical know-how; and
- Species characteristics that are suitable for aquaculture production.

As with other forms of farming, aquaculture involves substantial capital investment and many potential risks. It is overshadowed by five fundamental concerns:

1. Who will buy the resulting product?
2. How will the product be produced?
3. Will revenues adequately exceed costs?
4. How will the enterprise impact on the environment?
5. Can the industry be developed in a sustainable manner?

7.2 Establishment of an ecologically sustainable, commercially viable aquaculture facility

Economic viability assessments have been undertaken on a range of hypothetical and established aquaculture operations. These assessments are aimed at helping prospective farmers calculate the financial viability of their operations.

The assessments have also highlighted the overriding influence that bio-economic variables have on the viability of aquaculture ventures. Issues such as biological filtration efficiencies and scale of production are potentially critical or limiting factors for economic success.

Figures taken from the existing Murray cod industry in the eastern states of Australia suggest that a five tonne facility may produce fish at \$14.86/kg, while a similar production facility of 25 tonne may produce fish at \$10.90/kg (Rawlinson 2002). This clearly shows that long-term commercial viability is closely related to the scale of aquaculture operations.

Few facilities, if any, within Western Australia are currently producing in excess of 5 tonne, with most currently producing less than one tonne. From economic analysis, this would indicate (Rawlinson 2002) that these farms run the risk of revenues not exceeding costs over the longer term. While individual facilities may achieve economic gain in the short-term through the utilization of niche markets, it is unlikely that these small-scale operations represent long-term commercially viable options.

However, economic benefits are not the only valued outcome of such aquaculture activities. Practical experience gained through industry operations also leads to increased industry expertise, offering benefits to any developing aquaculture industry.

As detailed in section 1.2 of this discussion paper, any decision made in relation to the translocation of non-endemic species must consider potential social and economic benefits in the light of any potential biological or environmental risks. Therefore, it needs to be clearly demonstrated that such benefits are likely and of a significant nature at a State level, prior to considering any level of biological or environmental risk that may be associated with aquaculture activities.

However, it should also be considered that during early industry development periods, economic benefits may not be achieved immediately. They are more likely to be realized over the longer-term.

Overall, there are a range of issues that may limit the aquaculture of these three Murray-Darling species in Western Australia, including:

- The ability of domestic and international markets to support the required sustainable industry development.
- The ability of an industry based on these species to compete with other established Australian and overseas aquaculture operations in the longer term based on other finfish species.
- A lack of available information regarding the profitability of the aquaculture of these three species in Australia as a whole and in Western Australia.
- The territorial and cannibalistic nature of these three species and the associated low optimum grow-out densities when grown extensively in dams or ponds.
- The technical problems outlined within sections 7.2.4, 7.3.4 and 7.4.4, including the difficulty in obtaining high quality broodstock (Rowland, pers. com.).
- The risk of in-breeding due to the limited availability of broodstock in Western Australia.
- The associated risk of disease introduction, accentuated by the current dependency on inter-state fingerling supplies.
- The level of environmental risk represented by each species.
- The level of bio-security provided by the type(s) of aquaculture system(s) to be employed.
- A consideration for ecologically sustainable development principles, as outlined in section 2.2 in relation to both industry and facility development.

In addition to the constraints outlined above that apply to the three Murray-Darling species being considered for aquaculture, there are a number of other issues that will affect their potential. These issues will need to be addressed on a species-by-species basis to varying degrees, as identified in the following sections.

7.3 Golden perch

7.3.1 *Broodstock management of golden perch*

Currently, there is no production of golden perch in Western Australia.

In the eastern states, broodstock are usually kept in earthen ponds (usually of 0.1 hectare surface area) until required, but can be maintained in tanks with no apparent loss of fecundity or egg and sperm viability (Thurstan, pers. com.).

Adult female golden perch mature, but rarely spawn naturally, in ponds. Consequently, they are usually induced to spawn with the use of hormone injections, i.e. hCG (human Chorionic Gonadotrophin) or carp gonadotrophins (Rowland, 1983a). Golden perch are batch spawners, with all eggs shed in a single spawning act (Mackay, 1973).

The size of the broodstock ponds varies. However, at the Narrandera NSW Fisheries complex, ponds are usually between 0.1 to 0.2 hectare in size, with golden perch (one to three kg) stocked at densities up to 200/ha (Rowland, 1994).

No methods are currently available to either manipulate the sex or limit reproductive success (e.g. triploidy) for this species.

7.3.2 *Production of juvenile golden perch*

Larvae are hatched in incubators where they remain for five days and are then stocked directly into earthen ponds (Rowland, 1996). Although larvae can be grown in tanks, faster growth rates are usually attained in fertilised ponds.

Survival is directly related to the availability of suitably sized prey (Rowland, 1996). Ponds stocked 10 to 14 days after filling give best results in terms of survival. Juveniles are usually kept in these ponds until they reach approximately 30mm, at which point they are stocked into areas for restocking (Rowland, 1996). While they can tolerate high pH levels (up to 10) and low water quality, larval mortality at low dissolved oxygen levels can be high, and therefore aeration is often necessary (Rowland, 1996).

7.3.3 *Grow-out of golden perch*

Grow-out ponds for golden perch are usually simple earthen ponds that are supplemented with a suitable fish food (preferably live food) to enable higher densities to be cultivated. Although golden perch have been successfully weaned to accept artificial (pelletised) foods, most grow-out operations stock at densities that can be supported by the natural production of

the water body or incorporate yabbies and other smaller fish species (e.g. goldfish) for food (Thurstan, pers. com.; Rowland, 1994). While aquarium fish have been used for this purpose, such practices can result in the introduction of disease to aquaculture stock and would therefore be of concern in Western Australia.

7.3.4 *Aquaculture potential of golden perch*

While the hatchery techniques for golden perch are well understood, there has been limited successful aquaculture production of this species up till now. The optimal strategy for large-scale production of golden perch is yet to be established. This strategy would most likely involve initial intensive hatchery culture, followed by extensive rearing in ponds.

The successful culture of golden perch will depend on the considerations for, and knowledge of, the following technical/biological constraints:

- No intensive grow-out technology available.
- Broodstock management and spawning inducement methods using hormones.
- Greater knowledge and technical requirements necessary for the management of fingerling production.
- Significant difficulties with weaning fingerlings (Rowland pers. com).
- Lack of information regarding optimum grow-out densities.
- Slow growth.
- Need to 'train' fish to take artificial foods, as live foods will be unavailable or unsustainable to most farmers.

Like both Murray cod and Australian bass, golden perch are top-order predators. These characteristics suggest that the species has the potential to have a significant impact on Western Australia's biodiversity through predation on a range of its aquatic species, including marron and other West Australian fish species. This apparent risk has raised a significant level of public concern about the use of golden perch in Western Australia.

Therefore, if this process provides any framework for the long-term aquaculture of golden perch, the use of this species will need to be fully assessed through Environmental Protection Authority processes before a final decision is made.

7.4 *Murray cod*

7.4.1 *Broodstock management of Murray cod*

Broodstock are usually kept in earthen ponds (0.1 to 0.2 hectare surface area) until required, but can be maintained in tanks with no apparent loss of fecundity or egg and sperm viability (Thurstan, pers. com.). Murray cod are usually kept at densities of 50 fish/hectare in earthen ponds, with higher densities not possible due to their aggressive and territorial nature (Rowland, 1988b). Handling of broodstock in the three months before a breeding season can cause atresia and reabsorption of oocytes (Rowland, 1988b).

A rise in water level is not required to induce spawning and cod will spawn readily in breeding ponds, as long as suitable spawning substrate is supplied (Rowland, 1983b). This

usually involves the use of mesh in a drum that can be easily removed once fish have spawned (Thurstan, pers. com.). If the eggs are not removed, some losses to invertebrate predation may occur (Thurstan, pers. com.).

Eggs and sperm of mature Murray cod can be stripped and fertilised in the laboratory, as eggs only become adhesive when exposed to freshwater. They can be easily handled for up to 30 hours in a weak saline solution with little loss of viability (Rowland, 1988b; Thurstan, pers. com.).

The success of inducing ovulation by using hormones is dependent on accurately assessing the ovarian development prior to injection (Rowland, 1988b). For example, if hormones that have atretic oocytes are injected into Murray cod, ovulation will not be induced. Furthermore, incorrect doses can either fail to induce ovulation or can lead to a lower hatchability of eggs.

Another critical factor in the production of viable eggs is the timing of stripping and fertilization, with a high hatchability of eggs stripped 45 or 46 hours after injection compared to a hatchability of only one per cent of eggs stripped 47 hours after injection (Rowland, 1988b). Fertilised eggs can be incubated in drums or trays with an adequate water flow (and aeration) until most eggs have hatched. Larvae then either fall to the bottom or are siphoned off (Rowland, 1988b; Thurstan, pers. com.).

Although Murray cod can be artificially induced to spawn with the use of hCG, some aquaculture systems obtain eggs from fish that mature and spawn in the breeding ponds (on structures provided) during the natural breeding season. However, these techniques require a thorough knowledge of the fish's reproductive developmental stage, biology and behaviour.

Live food, including goldfish (*C. auratus*) and yabbies (*C. destructor*), are periodically fed to broodstock (Rowland, 1988b). Again, due to disease implications as described in section 7.3.3, the sourcing of feed fish from aquarium fish sources would be of concern in Western Australia.

No methods to limit the reproductive success (e.g. triploidy) or control the sex have been refined for Murray cod.

7.4.2 Production of juvenile Murray cod

While juveniles may soon be available from within Western Australia, all are currently produced and supplied from the eastern states. Eggs are adhesive and hatching ranges from between four (at 24.1 to 25.3°C) and 10 (at 16.8 to 17.8°C) days (Rowland, 1988b). Most aquaculture techniques suspend the fertilised eggs (attached to the spawning mesh) in tanks and allow newly hatched larvae to settle on a fine mesh on the bottom of the tank, before being siphoned off.

Although larvae can be successfully grown in tanks, most systems obtain much faster growth rates and better individual condition with the use of outdoor nursery ponds that have been fertilised and seeded to encourage zooplankton blooms (Rowland, 1996; Lovric, 2000). If initial feeding is delayed by five or more days after the completion of yolk-sac absorption, larval survival is significantly reduced at low zooplankton densities, i.e. less than 250

zooplankton/litre (Rowland, 1992). If feeding is not delayed, larvae can survive on zooplankton at densities of 250 – 5,000/litre.

Murray cod larvae and juveniles are usually kept in these nursery ponds until they reach a suitable size for transportation into the wild or into grow-out ponds, usually 45 mm and 60 days old (Thurstan, pers. com.). They are also being cultured at high densities in recirculating aquaculture systems or in a combination with ponds, during the warmer months (Rowland, pers. com.).

7.4.3 *Grow-out of Murray cod*

Historically, most grow-out of Murray cod has been undertaken extensively in farm dams, as it was originally thought that the cod was unsuitable for intensive culture due to its aggressive and territorial nature. However, it was discovered that stocking of Murray cod at high densities actually reduces both the opportunity for the cod to establish territories and its aggressiveness towards other tank members. More uniform growth is also achieved.

Consequently, the extensive method of culture results in lower yields and variable growth rates in comparison with intensive closed recirculating aquaculture systems (RAS). It is on this basis that future commercial production from extensive culture is likely to be limited, and that industry growth will be derived from large-scale intensive closed RAS (Department of Natural Resource and Environment Victoria and New South Wales Fisheries).

In 2000, there were 25 farms in three states producing Murray cod. However, the majority of the production comes from a few well-designed, capital intensive (equipment capital outlay of approximately \$500,000), closed recirculation aquaculture systems (Lawson, pers. com.).

These systems provide oxygen supplementation for maintaining high stocking densities required for uniform growth and high yields. Excluding industry developments in Western Australia and Queensland, there are 62 licensed Murray cod farms, with 15 providing fingerlings for sale, 19 providing table fish for sale, and the balance of the farms licensed but not yet producing (Lawson 2002).

Extensive ponds

Grow-out ponds for Murray cod are usually simple earthen ponds that are supplemented with a suitable fish food to enable the production of higher densities of fish. Although Murray cod have been successfully weaned to accept artificial (pelletised) foods, most grow-out operations stock at densities that can be supported by the natural food production of the water body, with the occasional addition of yabbies and goldfish for supplementary feeding (Rowland, 1988a; Thurstan, pers. com.).

The territorial nature of Murray cod, their fast growth rate and the large size attained by this species means that grow-out densities are usually lower than other freshwater fishes such as golden perch and silver perch, with 50 fish/hectare being close to the maximum (Rowland, 1988a). Extensive pond systems are generally only utilized for fingerling production to support recreational stock enhancement programs in Australia's eastern states.

Pond-based cage culture

While cage culture has not been adopted as a commercial practice, two non-replicated multiple cage culture trials were conducted at the Marine and Freshwater Resources Institute in Snob's Creek, Victoria from January to March 2001 and February to May 2002.

The first trial experienced adverse environmental conditions (high water temperatures and algal blooms) and achieved poor results. The second trial, stocked at three different densities with fish of three different initial starting weights, resulted in food conversion rates of 1.5 to 2.7 (mean 1.9) with a final stocking density of 43kg/m³ (Ingram 2002).

Closed re-circulating aquaculture systems

Basic intensive recirculation aquaculture systems (RAS) consist of a number of tanks (usually 1,000 to 1,300 litres in size) housed within a vermin proof and preferably climate controlled room or shed. Tanks are independently or group filtered by both mechanical and bio-filters, which are used to strip solids, nitrogenous waste and nutrients from the water.

Recirculation systems can also incorporate a number of other treatment units, including UV and ozonation systems to disinfect water, and protein skimmers to remove protein-based waste. After passing through the filters, the water is then recycled back to the tanks. The use of oxygen supplementation is generally applied to maintain high stocking densities, rather than for filtration or water sterilisation purposes.

Fingerlings for intensive RAS production can be purchased from a number of hatcheries, once they are weaned onto commercial pellet diets. Once quarantined and settled, fish are ready for stocking into tanks. Stocking rates in tank systems vary, depending on the capacity of the system and the intensity of the operation. In well-developed and highly advanced systems, stocking rates of up to 100-250kg/m³ may be obtained, with current oxygen injection systems available.

Without oxygen injection systems, stocking of closed RAS is limited to around 50kg/m³. Oxygen injection techniques have not yet been adopted by the Western Australian aquaculture industry.

Murray cod require high protein diets, usually in extruded pellet form, available in various classes, depending on the size of the fish. Food conversion ratios (FCRs) for Murray cod have been reported from industry as low as 0.8:1 (kg of food: kg of growth), yet farmers should expect FCRs closer to 1.5 to 2:1. The use of intensive systems also means that the fish can be kept at optimum growing temperatures all-year-round, allowing farmers to potentially achieve a market size of 500 to 600g in around 12-18 months.

7.4.4 *Aquaculture potential of Murray cod*

The commercial farming of Murray cod for consumption purposes in Australia is in its infancy, yet the biology and behaviour of this species is well understood. Any further industry development will be based on additional market development, adoption of suitable

production technology, adoption of appropriate environmentally sustainable requirements and whether all sectors of the industry can be profitable within a sustainable framework.

Separate to the supply of fingerlings for recreational stock enhancement purposes, the domestic market for farmed Murray cod, mainly in the eastern states, is largely undeveloped. Murray cod is either sold live, with other markets for whole gilled and gutted and fillets being established. To date, the majority of the product is sold live, with producers selling direct or through a distributor (Larkin and Ingram 2000).

As farmed Murray cod is an emerging industry, there is uncertainty as to whether current prices will be sustained if production increases.

The sale of live Murray cod has been very well received, and is perceived by some chefs to be one of the best tasting freshwater fish in the world (NSW Fisheries, 1998). Nevertheless, competition from other domestic freshwater finfish, imports and product quality are challenges facing this sector in the market place.

At this time, the most productive operations for growing Murray cod have been closed recirculating aquaculture systems, which are capital intensive and require specific management skills. Water quality and quantity is critical to Murray cod production, with levels of conductivity, hardness, chlorine (domestic supplies) and iron etc. being very important, and groundwater should be thoroughly tested (see Ingram & Larkin, 2000). However, there is an absence of optimal water quality data for Murray cod culture, both in earthen ponds and recirculating systems (Ingram & Larkin, 2000).

The successful culture of this species will depend on the considerations for, and knowledge of, the following technical/biological constraints:

- Use of intensive grow-out technology.
- Broodstock management and possible spawning inducement methods using hormones.
- Knowledge and technical requirements necessary for the management of fingerling production.
- High management requirements to counter severe growth variation and husbandry problems (Larkin and Ingram, 2000).
- Use of appropriate artificial feed to avoid such problems as fatty liver disease, which occur through feeding high fat diets to fish (Ingram & Larkin, 2000).

7.4.5 Aquaculture of Murray cod in Western Australia

The introduction of Murray cod into Western Australia has been undertaken on a number of occasions for recreational stocking, domestic stocking, and more recently, for aquaculture purposes. Records of such translocations date back as far as 1890s, and some of those undertaken for recreational stocking purposes resulted in short term establishment. However, they would not appear to have resulted in sustainable populations in the unrestricted aquatic environments in which they were introduced.

A small Murray cod industry currently operates in Western Australia, and is being managed under interim management arrangements prior to the final policy outcomes of this consultation process. These industry activities are generally limited to closed recirculated

aquaculture system conditions, and are currently dependent on fingerling supplies from the eastern states.

Under the current interim management arrangements, the Department of Fisheries has worked towards maintaining its commitment to the sustainable development of the Western Australian aquaculture industry. However, previous introductions of Murray cod have demonstrated that they are large, long-lived, top-order predators, which can establish feral populations in Western Australia. These characteristics suggest that this species has the potential to significantly impact on Western Australia's biodiversity through predation on a range of aquatic species, including marron and other local fish species.

This apparent risk has raised a significant level of public concern about the use of this species in Western Australia. Therefore, if this process provides any framework for the long-term aquaculture of this species, the continued use of this species will need to be fully assessed through Environmental Protection Authority processes before a final decision is made.

7.5 Australian bass

7.5.1 *Broodstock management of Australian bass*

Currently, there is no production of Australian bass in Western Australia. While this species is produced in the eastern states, there is no grow-out industry for Australian bass (Rowland pers. com.), and fish produced are generally for recreation stock enhancement purposes. For this reason, hatchery production of Australian bass depends on the capture of wild mature fish to ensure genetic consistency (Battaglione & Selosse, 1996).

While eggs and sperm will develop under pond conditions, fish will not normally spawn naturally in these ponds due to the absence of the flooding cue, necessitating the use of hormones (hCG) (van der Wal, 1989). Mature fish are kept in freshwater until induced to spawn using hCG (see Battaglione *et al.*, 1989; Battaglione & Selosse, 1996). After injection with hCG (see Battaglione & Selone, 1996, for doses), fish are kept in tanks where they spawn 34 hours after injection on average. However, in order to maximise hatch rate, stripping eggs 38 hours after injection is recommended (van der Wal, 1983; Battaglione *et al.*, 1989; Battaglione & Selone, 1996).

No methods to limit reproductive success (e.g. triploidy) have been refined for this species.

7.5.2 *Production of juvenile Australian bass*

Stripped and spawned eggs (approximately 1 mm) are incubated and aerated in saltwater of 30 to 35 ppt and hatch within two days at 18°C (van der Wal, 1983; Battaglione *et al.*, 1989). Newly hatched larvae are about 3.5 mm long (van der Wal, 1983).

Larvae of Australian bass are difficult to rear because they are small (~3.5 mm at hatching), poorly developed and require large quantities of live food of a suitable size when feeding begins (van der Wal, 1983; van der Wal & Nell 1986; Battaglione, *et al.*, 1989). As such, artificial food has not been successfully fed to Australian bass larvae (van der Wal & Nell, 1986).

Australian bass larvae reared in 28 to 34 ppt (i.e. seawater) achieved the highest survival and growth rates when fed at food concentrations of nine to 15 rotifers (*Brachionus plicatilis*)/ml for the first two weeks. Feeding rates of three to six rotifers/ml and 18 to 24 rotifers/ml resulted in reduced survival, growth rates and overall condition. Older larvae (~3 weeks after hatching and 6 mm in length) begin feeding on brine shrimp nauplii (*Artemia salina*) but show reduced growth at concentrations in excess of six shrimp nauplii/ml (van der Wal & Nell 1986; Battaglene, *et al.*, 1989).

Australian bass can be transferred to freshwater for to eight weeks after the completion of yolk absorption, when metamorphosis has taken place (van der Wal & Nell, 1986; van der Wal, 1989). However, later experimental work has shown that larvae can tolerate freshwater as early as 12 days after hatching (Battaglene, *et al.*, 1989). This need for saltwater organisms during the first four weeks of feeding has been identified as the 'critical period' for Australian bass aquaculture systems (van der Wal & Nell, 1986).

Although eggs hatch and larvae develop at salinities between eight to 14 ppt in the wild, optimum artificial propagation and survival has been achieved at salinities between 25 to 35 ppt (Battaglene, *et al.*, 1989). Larval survival in production trials is generally low, averaging at 22 ppt, and is highest in those trials with initial densities of fish less than 12 fish/l, or in tanks which support continuous algal blooms (Battaglene, *et al.*, 1989).

A recurrent cause of larval mortality is a handling or shock response affecting older fish (21+ days), apparently related to a nutritional deficiency from feeding solely on brine shrimp (Battaglene, *et al.*, 1989). Other factors causing mortality include the failure of larvae to develop functional swim bladders at the start of exogenous feeding, due to bright lighting, low salinities, turbulence and poor water quality (Battaglene, *et al.*, 1989).

7.5.3 *Grow-out of Australian bass*

Currently, there is no aquaculture industry based on the grow-out of Australian bass. They have been stocked in simple earthen ponds for recreational fishing purposes, where they can be supplemented with a suitable fodder fish to enable higher densities.

Although Australian bass have been successfully weaned to accept artificial (pelletised) foods, most stocking activities are undertaken at densities that can be supported by the natural production of the water body (Bardsley, pers. com.). They are quite hardy in farm dams and growth of 0.8kg in two years has been reported (Williams, 1964).

Stunting is a common problem encountered with the grow-out of Australian bass. Fish mature but do not grow, even at low densities – this situation is possibly due to their aggressive nature (Thurstan, pers. com.). Such characteristics are of significant importance when considering the species for aquaculture, but may also be of interest when stocking for recreational stocking purposes.

7.5.4 *Aquaculture potential of Australian bass*

While the hatchery techniques for this species are well understood, the optimal strategy for large-scale production of bass is yet to be established. The final strategy would most likely involve initial intensive culture in saltwater, followed by extensive rearing in either saltwater or freshwater ponds.

The successful culture of this species will depend on the considerations for, and knowledge of, the following technical/biological constraints:

- No intensive grow-out technology available.
- Broodstock management and spawning inducement methods using hormones.
- Use of appropriate food supplies for successful larval development.
- Greater knowledge and technical requirements necessary for the management of fingerling production.
- Difficulties in acclimatising larvae to freshwater.
- Do not respond well to artificial feeds.
- Propensity to stunt.
- Slow growth.
- Males being much smaller than females (and therefore not as valuable to aquaculture).

Like both Murray cod and golden perch, Australian bass are top-order predators. These characteristics suggest that this species has the potential to have a significant impact on Western Australia's biodiversity through predation on a range of aquatic species, including marron and other Western Australian fish species.

This apparent risk has raised a significant level of public concern about the use of Australian bass in Western Australia. Therefore, if this process provides any framework for the long-term aquaculture of this species, the use of this species will need to be fully assessed through Environmental Protection Authority processes before a final decision is made.

SECTION 8 RECREATIONAL STOCKING

8.1 Current freshwater recreational fishing opportunities

Western Australia has approximately 70 native freshwater fish species, and of these eight could be considered recreational angling species (e.g. barramundi, catfishes and grunners). These species are found almost exclusively in the Pilbara and Kimberley Regions. In the State's south-west, there are a number of estuarine fish species that are heavily targeted by anglers, some of which penetrate large distances up stream (e.g. black bream, yellow-tail trumpeters).

However, with the exception of freshwater cobbler (*Tandanus bostocki*) and marron, there are no native freshwater fish that provide recreational fishing opportunities in the south-west. Those species that are targeted by freshwater fishers have been introduced into the waters of inland Western Australia, for example, brown and rainbow trout, and redfin perch, as well as one species of decapod crustacean, the yabby.

A licence is required to fish for all freshwater fish in waters south of Greenough (29° S latitude) and above the tidal influence, including all lakes, dams, rivers and their tributaries. For the 2002/03 season, 3,567 freshwater angling licences and 5,101 recreational marron licences were issued. A further 12,778 umbrella licences were issued which permitted licence holders to participate in freshwater fishing and marroning.

8.2 Proposed recreational species

Golden perch, Murray cod and Australian bass have been identified by the Recreational Fishing Advisory Committee (RFAC) as possibilities for enhancing recreational fishing opportunities on the basis that:

- Each of these species provides good recreational fishing qualities.
- They generally have high survival and grow to relatively large sizes (see Figures 2 and 3).
- They have very good eating qualities.
- The technology exists for fingerlings to be produced in commercial quantities, which is an important feature if considering establishing "put and take" fisheries.

The range of environments that have been potentially considered for recreational fishing enhancement through translocation include:

- Unrestricted aquatic environments (for example, rivers, creeks or adjacent flood prone dams).
- Artificial dams (i.e. for drinking and irrigation purposes).
- Fully enclosed water bodies.

8.3 Establishment of a recreational fishery in unrestricted freshwater environments

All three Murray-Darling species proposed for introduction are top-order predators (an attribute that explains their favour among freshwater anglers). Consequently, for their

successful introduction and survival into inland Western Australia, appropriate prey species are required. Prey species in Western Australia are likely to include a large proportion of fish and/or decapod crustaceans, including marron.

The theory of energy flow through food chains and webs suggests that only a small amount of energy is used between trophic levels as growth is approximately 10 per cent, with most energy lost through physiochemical processes such as heat, digestion, feeding, etc (Krebs, 1985). The implications of this in Western Australia are:

1. Given the naturally low productivity of Western Australian inland waters (Bunn and Davies, 1990), there is a limit to the total amount of available energy, and this may be below that required for the long-term support of even a modest fishery of these species.
2. A fishery based on a species that preys mainly on marron must always be smaller (in terms of total population energy) than the marron fishery within which it occurs.
3. It is possible that the replacement of trout for another species may occur (i.e. there may not be enough population energy to support additional species); and
4. It is possible that the establishment of additional species may not increase opportunities for recreational fishing participation or catches, but may only diversify fishing opportunities.

In addition, there is evidence to suggest that redfin perch already established in Western Australia may have adversely impacted on at least one of the species proposed for translocation (Murray cod) within its natural distribution (Rowland, 1989). It is also likely that it has had an effect on the other two Murray-Darling species being considered within this paper.

Furthermore, redfin perch have been shown to consume large numbers of newly released trout fingerlings when the latter are stocked into waters where the former live (Baxter *et al*, 1985, Molony, pers. com). Therefore, the implications of the presence of redfin must be considered in relation to the establishment of any recreational fishery.

The predatory impact of redfin perch may be minimised if older/larger fish (of the other species) are stocked. However, this has additional cost implications and aquaculture limitations that may limit or prohibit the production of older/larger fish for these purposes.

While little information is available on the success of stock enhancements in eastern Australia of golden perch, Murray cod and Australian bass, previous studies have shown that the stocking of large numbers of hatchery-reared trout are often associated with high mortalities, a poor return to anglers (as low as one to two per cent), and at a high cost to the funding body (Nicholls, 1958; Larsen, 1972; Creswell, 1981; Bachman, 1984; McDowall *et al.*, 1985; Davies *et al*, 1988). These and similar issues would need to be considered prior to stocking any of these Murray-Darling species, to establish the likely benefits, if any, that may be achieved.

Any decisions regarding the introduction of the three Murray-Darling species should be made with future generations in mind. Introductions should be seen as irreversible, with eradication almost impossible (Arthington, 1991). It is worth noting that some Murray-Darling species have been introduced from time-to-time into Western Australia since the late 1800s, with limited success at stock establishment so far. However, stocking results have shown that sustainable populations can be achieved through considered stocking programs in suitable

waters. It should also be noted with the introduction of any species, multiple stocking efforts are often required to establish sustainable populations.

Any species with environmentally or biologically (triploid) restricted reproductive capabilities may provide further controls for potential recreational stocking activities. Likewise, species longevity is important when considering unsustainable populations where no other control options are available.

8.3.1 *Recreational fishery risks and benefits in unrestricted aquatic environments*

As experienced with the recreational trout fishery, which has been established in unrestricted aquatic environments within Western Australia, it is possible, through appropriate development, to ensure communities are provided with greater recreational fishing opportunities. The potential therefore exists for an economic flow-on for local businesses such as boat-hire, fishing guides, bait sales, accommodation facilities and restaurants through the establishment of freshwater recreational fisheries.

However, it should also be considered that the successful stocking of any of these species, in unrestricted aquatic environments, could result in direct predation on and competition with native Western Australian fish and crustaceans and other non-endemic species already present within the State, some which already provide economic benefits as described above.

While such an event would have environmentally significant implications, it is also likely to exert further pressure on other established freshwater recreational fisheries, such as marron and trout. This disruption could result in the reduction of existing freshwater fishery quality or existence, and thereby a decrease overall in recreational fishing opportunities. This could also lead to the decline of established tourism operations and other economic ‘flow-ons’ for local businesses.

8.4 Alternative recreational fishing opportunities

While the stocking of unrestricted aquatic environments with the three Murray-Darling species may present a number of significant environmental and recreational concerns related to a range of stakeholder groups, additional recreational fishing opportunities may be developed through the stocking of other areas and/or the consideration of other available species.

Other species may represent less or no additional environmental and/or biological risk, and consequently prove to be suitable for recreational stocking applications. Otherwise, additional recreational opportunities may be developed through the stocking of more bio-secure environments, such as isolated or impounded water bodies, as suggested by the Recreational Fishing Advisory Committee.

When considering stocking impounded water bodies with Murray-Darling species:

- Golden perch may only be stocked at low densities, due to their aggressive nature and dependency on live food sources.
- Murray cod may only be stocked at low densities, due to their aggressive nature, fast growth and dependency on live food sources.

- Australian bass may only be stocked at low densities - and tend to stunt - due to their aggressive nature, and are dependent on natural pond production for live food sources.

In comparison, black bream, silver perch and rainbow trout may be stocked at high densities, do not tend to stunt, are not aggressive, take artificial feeds and are generally considered as high-value recreational species, with both good sporting and eating qualities. However, the stocking of black bream is limited to saline water bodies, as the species is incapable of tolerating freshwater environments.

In Western Australia, the two non-endemic species of rainbow trout and silver perch are currently available for recreational stocking purposes. The stocking of rainbow trout is subject to translocation approval and the stocking of silver perch may be undertaken as described in Fisheries Management Paper 107.

Therefore it would seem that consideration should be given to the areas stocked and the use of other available species for recreational stocking purposes prior to the translocation of additional non-endemic species - which may offer few additional benefits and greater environmental risks.

As previously described in sections 4, 5 and 6, the three Murray-Darling species discussed are top-order predators. These characteristics suggest that these species have the potential to significantly impact on Western Australian biodiversity through predation on a range of aquatic species, including marron and other Western Australian fish species.

This apparent risk has raised a significant level of public concern about the use of these Murray-Darling species in Western Australia. If this process provides any framework for the recreational stocking of these species, their use will need to be fully assessed through the Environmental Protection Authority processes, before a final decision is made.

SECTION 9 ENVIRONMENTAL ISSUES

9.1 Impact on the environment and other aquatic species

While this discussion paper addresses potential aquaculture *and* recreational stocking activities, the risk of releasing the three Murray-Darling species into any Western Australian aquatic environment will vary, depending on the activity being considered.

Regardless of the reason or cause for release, there are a number of possible detrimental effects that may result from the translocation and release of any species. These include: additional competition for food and space, predation, alteration of food chains and webs, alteration of habitat, disease introduction, and loss of genetic integrity and diversity.

While disease introductions are often irreversible, the subsequent establishment of non-eradicable population may also result in other impacts being experienced on a long-term basis.

Predation and competition are the main interactions likely to be experienced between the three Murray-Darling species and other Western Australian fishes. The three Murray-Darling species proposed are known predators, utilising a diversity of prey species including fish, birds, mammals, amphibians, aquatic insects, terrestrial insects and crustaceans. A number of these are listed as 'rare', 'threatened or 'protected' in Western Australia.

As well as predation, the main impact likely to be experienced by West Australian fish species is competition for limited resources. The demand of two species that exist at the same trophic level for a resource that is actually or potentially limiting (such as available food/habitat), is accepted as evidence for competition. A large overlap often occurs in the diets of the introduced fish and native fish in a given system. The extent to which the species can coexist depends on both the extent to which resource partitioning can occur and the availability of resources within that system (Arthington, 1991).

Due to the limited resources within Western Australian aquatic systems and the similarity between juvenile Murray cod and the endemic night fish (*Bostockia porosa*), a significant level of competition is expected where the distribution of these two species overlaps.

In general, the level of risk represented to all West Australian fish populations will depend on the proposed stocking areas that may result from this policy formulation process and the distribution of existing native fish populations. Where these areas overlap, some deleterious impacts are likely to be experienced by these Western Australian species and the level of the acceptability or risk of such impacts will need to be assessed.

9.2 Genetic integrity and diversity

As these three Murray-Darling species do not naturally occur in Western Australia and no similar species exist to the extent where hybridization is likely to be successful, the issue of impacts on the genetic integrity of Western Australian native fish species is not an issue. As mentioned in section 9.1, the Western Australian native species that is most similar is the

endemic night fish (*Bostockia porosa*). This is an identical *Percichthyidae* species to the Murray cod, except for its maximum size is limited to 150 mm, in comparison to that of the Murray cod which has been recorded up to 1,800 mm in total length.

In contrast, the release of any predatory non-endemic fish into Western Australia could pose a significant threat to West Australian native fish populations within any target system. This could result in population fragmentations, extinctions, competition and disruptions to food chains and webs. It is likely that any top-order predator, such as golden perch, Murray cod or Australian bass, could threaten the genetic diversity of Western Australian native species.

For example, the recent local extinctions of the mud minnows (*Galaxiella munda*), western pygmy perch (*Edelia vittata*) and night fish (*Bostockia porosa*) from the upper reaches of Big Brook (above the dam), have 'coincided' with a recent (1992/93) introduction and subsequent establishment of redfin perch (*Perca fluviatilis*) (Pen *et al.*, 1988, 1991; Morgan & Gill, 1996).

9.3 Diseases and parasites

The introduction of associated parasites and disease remains a risk with the translocation of any fish species into and within Western Australia. Yet this risk can be reduced through translocation, quarantine and disease testing protocols.

While these protocols reduce risk, they do not eliminate it, so there is always a risk of disease introduction with any translocation. Furthermore, the effect of a parasite or pathogen on a novel host is often more severe than the effect on the host with which the organism co-evolved (Arthington, 1991).

Most diseases reported for the three Murray-Darling species involve outbreaks of naturally occurring pathogens, usually exacerbated by stress to the fish (i.e. overpopulation, extreme water temperatures, etc.). The known diseases of Australian fish have been reviewed by Callinan (1988), Rowland and Ingram (1991), Callinan and Rowland (1995) and Humphrey (1995).

There has been little targeted surveillance of fish populations in Australia, and the disease information is certainly incomplete. Mortalities of Murray cod due to an undescribed iridovirus (not epizootic haematopoietic necrosis virus) were reported at a farm in the Murray-Darling basin in 2003 (B. Jones, pers. com.).

While hatchery-reared fish often develop diseases such as white spot, tail or fin rot and *trichodiniasis*, of more concern to the relatively disease-free status of Western Australian fish are goldfish ulcer disease, epizootic haematopoietic necrosis virus (EHNV) and viral encephalopathy and retinopathy (VER) (Callinan & Rowland, 1995; Thorne, 1995). As of September 2003, there was no evidence that these diseases were present in Western Australia. The status of goldfish ulcer disease in the eastern states is uncertain, but EHNV and VER are apparently not uncommon in fish in south-eastern Australia.

In Australia, the known range of species that are affected by EHN virus includes redfin perch, rainbow trout, Macquarie perch, silver perch, mountain galaxias, sheatfish, catfish and

mosquito fish. This information, based on limited testing of native fishes within Australia, indicates that most freshwater teleost fish are probably susceptible to this virus.

Across all age classes, it has been shown that EHNV need not be associated with clinically detectable disease in the population, and can be readily and inadvertently transferred with shipments of live fish. Therefore, taking into account the expected range of likely host species and the cryptic nature of the virus, it is reasonable to assume Murray cod is an effective host.

The Department of Fisheries has checked with the International Reference Laboratory for EHNV at the University of Sydney, Australia. The head of the laboratory, Professor Richard Whittington, has confirmed that there has been no testing of Murray cod for EHNV, but that it is considered to be a probable carrier.

The Viral Encephalopathy and Retinopathy (VER) disease has been reported to occur in at least 32 fish species from 16 families worldwide. It is noteworthy that the list of species found infected increased by 10 in two years.

In Australia, the VER disease is known to occur in barramundi, catfish and sleepy cod. Under experimental conditions in Australian laboratories, the virus transmits to golden perch, silver perch, barcoo grunter, silver trevally, estuarine cod and flounder. Thus, while the disease status of wild-caught Murray cod and Australian bass with respect to VER is unknown, they must be considered as potential carriers.

While it is not known whether Western Australia native fish are susceptible to the above diseases, some related species in eastern Australia certainly are (Crowl *et al.*, 1992).

As is the case for other non-endemic species entering Western Australia, all fish would need to be certified to the satisfaction of the Department of Fisheries' Senior Fish Pathologist prior to translocation. For the sustainable development of both the aquaculture industry and recreational activities, it is vital to ensure that the translocation of these Murray-Darling species into Western Australian is done in accordance with any disease certification requirements. These efforts will ultimately provide the appropriate level of protection to the Western Australian environment, native fish species and serve to protect all aquaculture and recreational fishery activities.

9.4 Impacts in context

There are several impacts that the establishment of any of the proposed Murray-Darling species could have on any Western Australian aquatic environment. Like most other species of predatory fish, such as brown and rainbow trout, they are opportunistic and are predicted to prey on a wide variety of food sources, particularly in prey-limited environments.

In Western Australia, the introduction of any of these Murray-Darling species will impact on West Australian native and endemic fauna (fishes, crustaceans and other species) due to the former's predatory nature.

Although these Murray-Darling species may have a negative impact on existing aquatic species, the level of impact relative to other factors must be considered. Throughout the

south-west, the stocking of both brown and rainbow trout, land clearing, water extraction, increasing salinity and other anthropogenic impacts have all resulted in major changes to the freshwater environment.

All these factors have also had a negative impact on the distribution and abundance of West Australian native fishes and crayfishes. The broader question in relation to the translocation of these Murray-Darling species is: What would be their impact on West Australia's aquatic fauna in relation to, or in addition to, other impacts (such as land clearing)?

Unfortunately, due to the long history of changes in land and water management (in excess of 150 years) and the long history of trout stocking in WA (approximately 100 years), being able to quantify the impact of each factor, including trout, is difficult. However, there is good anecdotal evidence available from Western Australia that indicates changes in land practices have a far greater negative impact on aquatic fauna than the predatory effects of trout, for example. For instance, only a small proportion of the Swan-Coastal catchment (watershed 616, where the Perth metropolitan area is located) was stocked with trout - in relatively small numbers - and most waters have been unstocked since at least 1970.

However, many of the species of West Australian native and endemic fishes that were originally present in the Swan-Coastal catchment have disappeared. This is most likely due to a combination of anthropogenic factors, including clearing and land development, flood mitigation and the introduction of other exotic species capable of breeding and dominating the remnant aquatic areas (such as the mosquito fish, *Gambusia*). As a result, the ranges of many species of south-west native fishes have contracted significantly within this catchment (Morgan et al. 1998).

Therefore, changes in land and water management in the other south-west catchments are likely to have major impacts on West Australian native aquatic fauna. It should also be considered that there is further anecdotal and research evidence to indicate that the most dominant species of fish in the south-west are the predatory introduced redfin perch (*Perca fluviatilis*), which dominates the predatory fish fauna. This species has already had dramatic effects on the natural populations of the proposed Murray cod within its natural distribution in the eastern states, and is likely to have had an effect on natural populations of Australian bass and golden perch in the eastern states.

Towards the quantification of individual impacts, Wager and Jackson (1993) nominated either salmonids or *Gambusia* as the main threat to 42 per cent of the eight per cent of Australian endemic freshwater fish species listed as endangered. For the remaining 58 per cent of endangered fishes, they nominated human processes as being the causative agent.

Indeed, it is generally recognised that destruction of freshwater habitats from land and water management practices is the single largest threat to Australia's endemic fish fauna, greater than competition with introduced fish or fishing pressures (Weatherley and Lake, 1967; Cadwallader, 1978; Harris, 1984; Merrick and Schmida, 1984; Welcomme, 1984; Michaelis, 1989; Moberly, 1993; Wager and Jackson, 1993).

Ultimately, while reading the preceding sections, the reader must bear in mind the likely impacts of the proposed Murray-Darling species relative to, and in conjunction with, other major changes in the south-west, including land clearing, water diversion, increasing salinity

and the effects of other introduced species. However, this does not provide justification to support additional activities of a non-sustainable nature.

SECTION 10 CONCLUSIONS

This discussion paper has been prepared as part of an overall consultation process to assist in the determination of an appropriate policy and management framework for the translocation of golden perch, Murray cod and Australian bass into and within Western Australia. It addresses the translocation of these three Murray-Darling species for the purposes of recreational stocking, domestic stocking, commercial and non-commercial aquaculture. The policy will provide information for which purposes and under what conditions the translocation of these species may or may not be undertaken.

Clearly, the translocation of any species must balance the economic and social benefits against the biological and environmental risks. The greatest risk common to each of the three Murray-Darling species relates to their predatory nature and potential to introduce disease.

The establishment of non-endemic diseases or any of these three Murray-Darling species in any Western Australian aquatic environment may lead to significant impacts on existing WA native species, resulting in a reduction in the State's natural genetic diversity and natural heritage. Any successful introduction may have a significant effect on existing marron and trout recreational fisheries, and thus potentially cause significant reductions in any existing social and economic benefits associated with these fisheries.

From the information available, it is reasonable to conclude that while there are potential gains from the introduction of these species, there are potential high economic and ecological risks associated with the stocking of these species. Therefore, any provisions made for the translocation of these species should be made with respect to the ecologically sustainable principles previously identified (Section 2.2).

10.1 Future policy on the translocation of golden perch, Murray cod and Australian bass

A draft policy on the translocation of golden perch, Murray cod and Australian bass for recreational stocking, domestic stocking, commercial and non-commercial aquaculture will be developed, following the release of this discussion paper and a review of all comments received on it. The draft policy is needed in response to the issues raised within this discussion paper and shall provide details on:

1. Conditions under which the translocation of golden perch, Murray cod and Australian bass, may be undertaken into and within Western Australia.
2. Conditions under which the stocking of golden perch, Murray cod and Australian bass may or may not be permitted, for the purpose of recreational stocking, domestic stocking, commercial and non-commercial aquaculture within Western Australia.

Following the receipt of comments on the draft policy, the Department of Fisheries will prepare and distribute a final policy to all interested stakeholders.

GLOSSARY

The following definitions apply to the words and terms used throughout this document.

Appropriate level of protection

The level of protection deemed appropriate by the State establishing measures to protect environmental health

Aquaculture

The production of fish for consumption purposes

Biosecurity

The level of prevention of the entry, establishment or spread of unwanted pests and/or disease in the environment

Broodstock

Adult fish used for the purpose of fingerling production

Closed recirculated aquaculture system

Typically, a recirculating aquaculture system (RAS) is often housed in an indoor facility, isolated from any external natural or artificial water bodies

Domestic stocking

The stocking of fish on private property for recreational purposes

Endemic

Native to and restricted to a particular geographical region

Ecologically Sustainable Development

Using conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased

Eutrophic

Depletion of oxygen during the summer by the decay of organic matter sinking to the bottom of a water body

Food chain

A sequence of organisms on successive trophic levels within a community, through which energy is transferred

Food web

The network of interconnected food chains of a community

Murray-Darling species

Golden perch, Murray cod and Australian bass

Native

Indigenous animal or plant

Non-endemic

A species that exists or is translocated beyond its natural range

Recirculating aquaculture system (RAS)

An aquaculture system primarily dependent on the recirculation of water to support all aquaculture production, often through the use of physical and biological filtration

Recreational stocking

The stocking of fish in public waters for recreational fishing purposes

Recreational Stock Enhancement

The stocking of fish to enhance existing populations

Resource partitioning

The differential exploitation of resources as a result of trophic or other species specialisation

Reverse sexual dimorphism

Two morphological types, female morph tending to be larger than the males

Sexual dimorphism

Two morphological types represented between the sexes

Translocation

Movement of aquatic organisms

Trophic level

The sequence of steps in a food chain or web from producer (plant) to primary, secondary or tertiary consumer

Unrestricted aquatic environments

Any water body other than impounded or isolated waters

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APPENDIX 1 SUGGESTED TOPICS AND ISSUES THAT MAY BE CONSIDERED FOR COMMENT

- Provision for and/or constraints on the translocation of Murray-Darling species into and within Western Australia for aquaculture purposes.
- Provision for and/or constraints on the translocation of Murray-Darling species into and within Western Australia for recreational stocking purposes.
- The recreational stocking of Murray-Darling species.
- The aquaculture of Murray-Darling species.
- Appropriate stocking condition for aquaculture purposes.
- Appropriate stocking conditions for recreational purposes.
- Social and economic benefits or loss from aquaculture activities.
- Social and economic benefits or loss from recreational stocking activities.
- Environmental benefit or loss from aquaculture activities.
- Environmental benefit or loss from recreational stocking activities.
- Disease introduction through aquaculture or recreational stocking activities.
- Protection of Western Australia's genetic diversity.
- Suggestions for the future policy on the translocation of Murray-Darling species for recreational stocking and aquaculture activities.

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- No. 3** Management Measures for the Shark Bay Snapper 1987 Season. P. Millington (1986).
- No. 4** The Esperance Rock Lobster Working Group. Chairman A. Pallot (1986).
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- No. 6** The King George Sound Purse Seine Fishery Working Group. Chairman R. Brown (1986).
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- No. 20** The Offshore Constitutional Settlement, Western Australia 1988.
- No. 21** Commercial fishing licensing in Western Australia. (1989)
- No. 22** Economics and marketing of Western Australian pilchards. SCP Fisheries Consultants Pty Ltd (1988).
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- No. 60** Bag and size limit information from around Australia (Regulations as at September 1993) F. B. Prokop (January 1993).
- No. 61** Economic impact study. Commercial fishing in Western Australia Dr P McLeod & C McGinley (October 1994)

- No. 62** Management arrangements for specimen shell collection in Western Australia. J. Barrington, G. Stewart (June 1994)
- No. 63** Management of the marine aquarium fish fishery. J. Barrington (June 1994)
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- No. 66** Future management of recreational gill, haul and cast netting in Western Australia and summary of submissions to the netting review. F.B. Prokop, L.M. Adams (September 1994)
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- No. 83** Translocation Issues in Western Australia. Proceedings of a Seminar and Workshop held on 26 and 27 September 1994. F. Prokop (July 1995)
- No. 84** Bag and Size Limit Regulations From Around Australia. Current Information as at 1 July 1995. Third Australasian Fisheries Managers Conference, Rottne Island. F. Prokop (July 1995)
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- No. 90** A report on the issues effecting the use of the Dampier Archipelago. Peter Driscoll, Landvision Pty Ltd (March 1996)
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- No. 144** The Translocation of Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) into and within Western Australia. Prepared by Jaqueline Chappell, contributions from Simon Hambleton, Dr Howard Gill, Dr David Morgan and Dr Noel Morrissey. (*not published, superseded by MP 156*)
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